OPTIMIZATION OF THE BOURGET WATER TREATMENT PLANT FOR CONTROL OF TRIHALOMETHANES

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Bourget

Water Treatment Plant for Control of Trihalomethanes

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EXECUTIVE SUMMARY

BACKGROUND

The two main objectives of the study are:

1. Improvement of the water treatment plant performance to meet the new Ontario Drinking Water Objectives (ODWO) THM guideline without compromising disinfection.

2. Sustaining long term performance through skills transfer to plant operating staff and recommendations for plant upgrades where required.

The optimization study was funded by the Ontario Ministry of Environment (MOE), and is a cooperative public/private project between the MOE and RAL Engineering Ltd. By optimizing the performance of their existing facilities, municipalities should be capable of producing water that meets the new THM objective, without requiring costly upgrades.

Trihalomethanes (THMs) are by-products created when the chlorine used in the disinfection process reacts with naturally occurring organics. Trihalomethanes are suspected of increasing the risk of cancer following long term exposure. The Ontario government has lowered the guideline from a maximum acceptable concentration of 350 µg/L, measured as a single occurrence, to an interim maximum acceptable concentration of 100 µg/L based on a running annual average of four quarterly samples.

The optimization of a water treatment plant consists of evaluating the existing treatment units, conducting laboratory testing to determine the best choice and dosage of the treatment chemicals and making changes to plant operation.

EXISTING CONDITIONS

Bourget is a small commuity located in Clarence Township south east of Ottawa. Its water supply is obtained from three wells, two deep wells (the MOE well and the Bourget well) and one shallow well or infiltration gallery/field drain system set in a hillside. The Bourget system uses a continuously pumped recirculation loop which passes water in storage from the base of the reservoir through the booster pump plant building returning to an above-surface discharge back in the storage tank. Sodium hypochlorite is added prior to the recirculation for disinfection.

A summary of historical data from January to December 1996 is presented as follow:

Parameters		*Range*	*Average*	
Colour	- MOE well:	38 to 39	38 TCU	
	- Bourget well:	37 to 41	39 TCU	
	- Infiltration gallery:	8 to 19	14 TCU	
	- Treated water:	11 to 14	12 TCU	
Turbidity	- MOE well:	0.1 to 0.6	0.4 NTU	
	- Bourget well:	0.8 to 2.3	1.5 NTU	
	- Infiltration gallery:	1.2 to 2.8	2.1 NTU	
	- Treated water:	1.0 to 1.8	1.3 NTU	
pH:	- MOE well:	8.9 to 8.9	8.9	
	- Bourget well:	9.0 to 9.0	9.0	
	- Infiltration gallery:	7.6 to 7.9	7.7	
	- Treated water:	7.7 to 8.8	8.5	
Alkalinity:	- MOE well:	406 to 408	407 mg/L	
	- Bourget well:	359 to 362	361 mg/L	
	- Infiltration gallery:	66 to 78	71 mg/L	
	- Treated water:	256 to 309	294 mg/L	
DOC:	- MOE well:	5.5 to 5.8	5.6 mg/L	
	- Bourget well:	5.5 to 5.5	5.5 mg/L	
	- Infiltration gallery:	2.4 to 4.3	3.3 mg/L	
	- Treated water:	4.2 to 4.9	4.6 mg/L	
Sodium:	- Infiltration gallery:	4.8 to 7.2	5.7 mg/L	
	- Treated water:	198 to 230	215.3 mg/L	
Aluminum:*	- MOE well:	2 µg/L	* January data only	
	- Bourget well:	85 µg/L		
	- Infiltration gallery:	100 µg/L		
	- Treated water:	42 µg/L		
Iron:*	- Bourget well:	0.16 mg/L	* January data only	
	- Infiltration gallery:	0.51 mg/L		
	- Treated water:	0.22 mg/L		
Manganese:*	- MOE well:	0.004 mg/L	* January data only	
	- Bourget well:	0.01 mg/L		
	- Infiltration gallery:	0.12 mg/L		
	- Treated water:	0.03 mg/L		

Parameters		*Range*	*Average*
THMs:	- Treated water:	255 to 326	273 µg/L
	- Distribution System:	216 to 360	295 µg/L
HAAs:*	- Treated water:	116 µg/L	* January data only
	- Distribution System:	104 µg/L	
Temperature:			
	- Collection Sump:	8 to 9 °C	12 °C (summer) 9 °C (winter)

Plant flows are generally: Average day 230 m^3/d
Maximum daily flow 300 m^3/d (summer).

PERFORMANCE ASSESSMENT

Disinfection of drinking water is the most important aspect of the treatment process. Harmful organisms in water such as bacteria, viruses or cysts can cause illness ranging from minor intestinal disorders to potentially fatal infections. Maintaining an effective disinfection system must be the overriding priority of the plant operations. For water supply under the influence of surface waters, chlorination with a 'free' residual is the most common and most practical method of disinfection. To be effective, the treated water must be very low in turbidity as suspended particles can shield bacteria and virus from the effect of chlorine. Turbidity levels greater than 0.1 NTU indicate an increased probability of chlorine resistant cysts being present.

The MOE guidelines recommend maintenance of a free chlorine residual at the end of the distribution system. The AWWA recommends a minimum residual of 1.0 mg/L of chloramine be maintained when chloramination is practiced, to prevent re-growth (AWWA, 1993).

A short circuiting factor T_{10}/T of 0.5 was used for the calculations representing the new condition in the storage tank after installation of a 75 mm nozzle to induce spiral flow. The pH of the raw water used for the calculations was 8.5. This parameter remains relatively constant through the year. The CT calculations were done under the most critical condition when the storage tank is half full for the summer maximum day demand (300 m^3/d). The minimum free chlorine residual required for inactivation of giardia cysts is 0.2 mg/L for an estimated contact time in the storage tank of 900 minutes (15 hours).

Preliminary results indicate that with a free chlorine residual in the re-circulating system of 0.3 to 0.4 mg/L, the levels of THMs vary from 50 to 80 µg/L during the winter and from 80 to 120 µg/L during the summer. However, THMs will continue to form in the distribution system with a free chlorine residual.

CONCLUSIONS

Since the Bourget water supply system does not include treatment units such as flocculation tanks, clarifiers or sand filters but only performs disinfection with chlorine, it is not feasible to improve further the quality of the treated water regarding colour, turbidity, and sodium levels which are above the ODWO guidelines.

The turbidity in the treated water representing a mix of the three sources of raw water varied from 1.0 to 1.8 for an average of 1.3 NTU. This is above the ODWO of 1 NTU and significantly exceeds the objective of this study of 0.1 NTU for protection against pathogen microorganisms. The MOE and the Bourget wells are deep therefore the presence of microorganisms such as cryptosporidium and giardia cysts is unlikely. However the shallow well which is essentially an infiltration gallery is under the influence of surface water and is susceptible to cysts contamination.

Further work concentrated on how to reduce the recirculation system and storage tank short circuiting to allow a reduction in the free chlorine residual in the storage tank and therefore THMs formation, while maintaining disinfection with a chlorine residual in the recirculation system. Future work to chloraminate distribution water was planned if found necessary.

RECOMMENDATIONS FOR PLANT SCALE MODIFICATIONS

The recommendations made to improve the disinfection efficiency and to reduce the levels of THMs for the Bourget water supply system are summarized as follows:

- Improve the chlorine contact time in the storage tank.
- Perform chloramination of the treated water entering the distribution system.
- Investigate an alternative treatment process.

It is also recommended to investigate additional deep well supplies to replace the infiltration well to reduce the risk of pathogenic organisms entering the water supply.

COST ESTIMATE FOR IMPLEMENTATION

The implementation of post-chloramination to reduce the level of THMs in the treated water involved the purchase of two day tanks and one mixer for a total cost of approximately $1,200. This cost was assumed by the MOE. The two dosing pumps required for the second injection point of sodium hypochlorite and for dosing ammonium sulphate were already available at the plant.

The installation of the 75 mm nozzle at the end of the storage tank inlet pipe to induce a rotation of the water in storage and reduce short circuiting to the outlet was done by the Town in the winter of 1997.
The additional operating cost related to dosing ammonium sulphate could not be estimated accurately since the exact dosage required was not known. However, it is estimated that the additional chemical costs will not be considerable.

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1.0 BACKGROUND

Trihalomethanes (THMs) are by-products created when the chlorine used in the disinfection process reacts with naturally occurring organics (eg. formed by decay of algae and vegetation) in raw water. Surface water containing high organics also often have high colour levels. The most common forms of trihalomethanes created are chloroform, bromodichloromethane, chlorodibromomethane and bromoform.

The formation of THMs is influenced by several factors:

- Free chlorine concentration - higher Cl_2 = higher THMs
- Organic content - higher organic concentration = higher THMs
- pH - higher pH = higher THMs
- Temperature - higher temperature = higher THMs
- Time - normally longer time = higher THMs

The formation of trihalomethanes is associated with the presence of organics in the water. This is often the case in inland lakes and rivers, which may contain more organics than large clear bodies of water have a greater trihalomethane formation potential, especially during periods of high runoff. It can also occur when groundwater sources draw water from aquifers high in organics.

The reason for adding chlorine to drinking water is to kill bacteria and other microorganisms that could cause numerous illnesses. However chlorine use leads to the presence of trihalomethanes and this is a cause for concern; studies have found an association between high levels of trihalomethanes in chlorinated drinking water, and slight increases in cancer following long term exposure of more than 35 years.

Chlorine has an advantage over other disinfectants in that it persists many hours or for days and provides protection for the entire water distribution system. The benefit to public health of using chlorine as a disinfectant in drinking water far out-weighs the risk to health associated with the low levels of trihalomethanes created as by-products of chlorination.

In order to decrease the health risk from trihalomethanes, the Canadian and Ontario governments have lowered their respective guideline limits from an "anytime" maximum acceptable concentration of 350 µg/L, measured as a single occurrence, to an interim maximum acceptable concentration of 100 µg/L based on a running annual average of four quarterly samples.

Owners of water treatment plants and water distribution systems who provide water for consumption have legal responsibilities which are shared by all suppliers of food or drink. Owners and suppliers must take reasonable measures to ensure the water is fit for safe consumption.

This optimization study is funded by the Ontario Ministry of the Environment (MOE), and is a cooperative public/private project between the MOE and RAL Engineering Ltd. By optimizing the performance of their existing facilities, municipalities such as Bourget should be capable of producing water that meets the new THMs objective, without resorting to costly upgrades. The optimization of a water treatment plant consists of:

- Documentation of existing facility.
- Assessment of the performance of the water supply system.
- Make required changes to plant operation at full-scale to ensure that changes will minimize the formation of THMs, but will not compromise the disinfection requirement.

2.0 OBJECTIVES

The two main objectives of the study are:

1. IMPROVEMENT OF BOURGET WATER TREATMENT PLANT PERFORMANCE

- Improve plant performance without major capital/equipment expenditures. Specific water quality objectives are listed below:

  i To comply with the 100 µg/L ODWO for THMs in treated water as a running annual average of 4 quarterly samples. This objective shall be met while ensuring proper removal and/or inactivation of disease-causing microorganisms such as bacteria and viruses, since this remains the most critical aspect of drinking water treatment.

  ii To investigate alternative treatment methods to reduce the colour level in the treated water.

2. SUSTAINING LONG-TERM PERFORMANCE

- Skills transfer to plant operating staff to enable them to effectively control and adjust processes over the long term.

- Documentation of plant conditions with recommendations for up-grades and operational modifications.

3.0 DOCUMENTATION OF EXISTING CONDITIONS

Bourget is a small community of about 1000 people located in Clarence Township south east of Ottawa. Its water supply is obtained from three wells, two deep wells (the MOE well and the Bourget well) and one shallow well or infiltration gallery. The two deep wells are the main production wells with a listed capacity of 250 L/min, while the shallow well has a production of 70 L/min. The water from the three wells is discharged to a collection sump. Raw water from the collection sump is transfered by the make-up pumps into a 750 m^3 (hydraulic volume) ground level storage tank. The operation of the make-up pumps is controlled by level sensing signals from the storage tank. The collection sump and make-up pumps are located in the make-up plant building.

The Bourget water system uses a continuously pumped recirculation loop which passes water in storage from the base outlet of the reservoir through the booster pump plant building returning to an above-surface discharge back in the storage tank. Sodium hypochlorite is added prior to the recirculation pumps. A chlorine level sensor and injection system on this loop, both of which are located in the booster pump plant building, are used to maintain a free chlorine residual of approximately 0.7 mg/L. The chlorine provides disinfection and some bleaching of the colour which is present in the well water due to natural organic material. The high lift pumps supplying the distribution system are also located in the booster pump building. A schematic of the Bourget water supply system is presented in Figure 3.1.

The water supply system consists of:

- ⇒ Two deep wells (the MOE well and the Bourget well).
- ⇒ One shallow well (infiltration gallery).
- ⇒ One collection sump.
- ⇒ Make-up pumps.
- ⇒ Recirculation pumps with a recirculation loop.
- ⇒ Sodium hypochlorite injection system for disinfection.
- ⇒ High lift pumps.
- ⇒ One ground level tank (750 m^3 working volume).

Plant flows are generally:	Average daily flow	160 L/min (230 m^3/d)
	Maximum daily flow	210 L/min (300 m^3/d – summer)
	Nominal system capacity	320 L/min (460 m^3/d)

Currently, the water supply from the deeper wells does not meet the summer demand indicating that the actual yield for the deep wells is less than 250 L/min. The water demand is also expected to increase since the Town is in the process of adding 150 new homes, and is planning to add 100 more in the future.

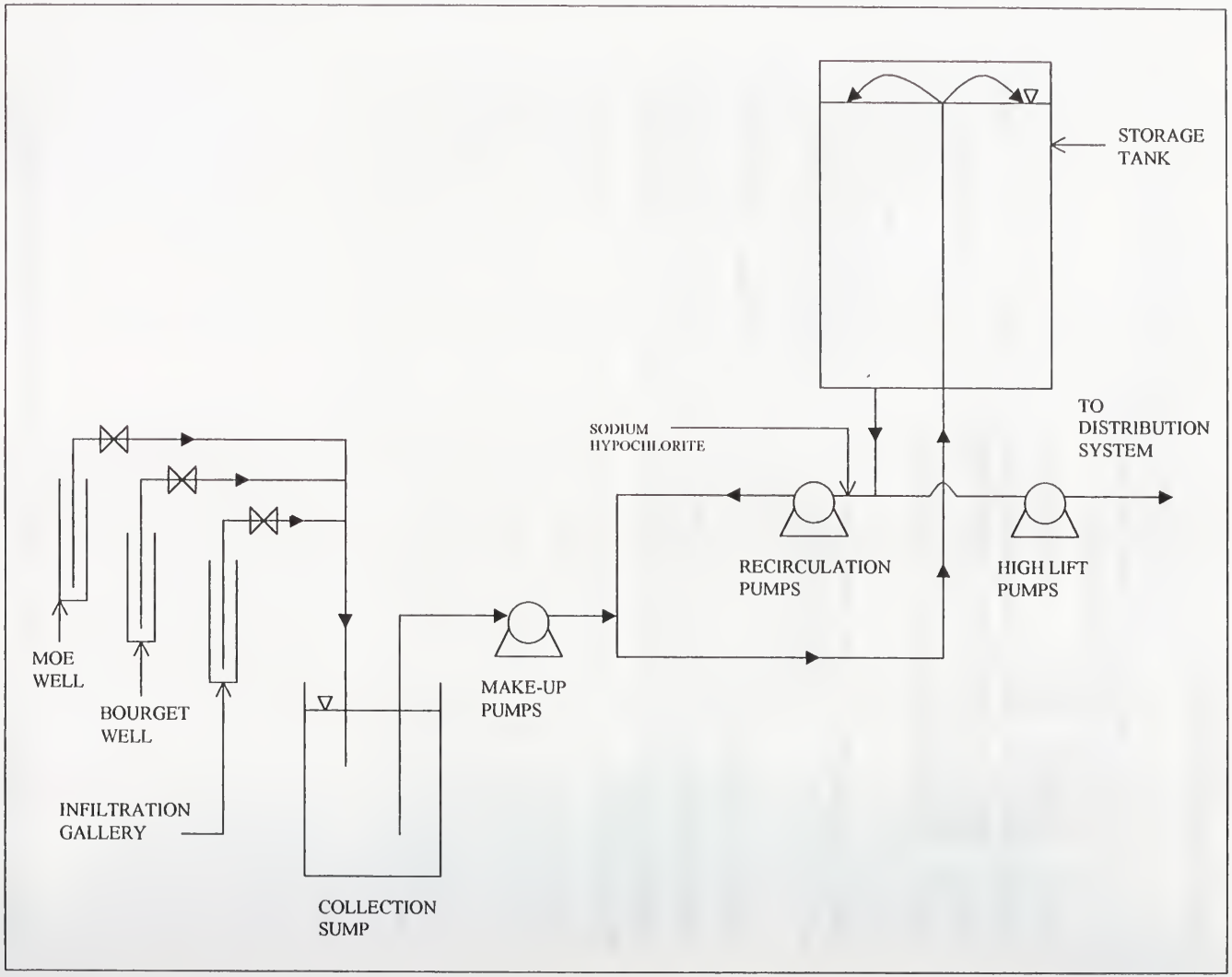

FIGURE 3.1 BOURGET WATER SUPPLY SCHEMATIC

3.1 HISTORICAL DATA FOR 1996

A summary of historical data from January to December 1996 is presented in Table 3.1. The table is a summary of concentrations measured for turbidity, colour, pH, aluminum residual, iron, manganese, trihalomethanes (THMs) and haloacetic acids (HAAs) for the raw and the treated water. The range and annual average from the data in Table 3.1 are summarized below:

Parameters		*Range*	*Average*
Colour	- MOE well:	38 to 39	38 TCU
	- Bourget well:	37 to 41	39 TCU
	- Infiltration gallery:	8 to 19	14 TCU
	- Treated water:	11 to 14	12 TCU
Turbidity	- MOE well:	0.1 to 0.6	0.4 NTU
	- Bourget well:	0.8 to 2.3	1.5 NTU
	- Infiltration gallery:	1.2 to 2.8	2.1 NTU
	- Treated water:	1.0 to 1.8	1.3 NTU
pH:	- MOE well:	8.9 to 8.9	8.9
	- Bourget well:	9.0 to 9.0	9.0
	- Infiltration gallery:	7.6 to 7.9	7.7
	- Treated water:	7.7 to 8.8	8.5
Alkalinity:	- MOE well:	406 to 408	407 mg/L
	- Bourget well:	359 to 362	361 mg/L
	- Infiltration gallery:	66 to 78	71 mg/L
	- Treated water:	256 to 309	294 mg/L
DOC:	- MOE well:	5.5 to 5.8	5.6 mg/L
	- Bourget well:	5.5 to 5.5	5.5 mg/L
	- Infiltration gallery:	2.4 to 4.3	3.3 mg/L
	- Treated water:	4.2 to 4.9	4.6 mg/L

Parameters		*Range*	*Average*
Sodium:	- Infiltration gallery:	4.8 to 7.2	5.7 mg/L
	- Treated water:	198 to 230	215.3 mg/L
Aluminum:*	- MOE well:	2 µg/L	* January data only
	- Bourget well:	85 µg/L	
	- Infiltration gallery:	100 µg/L	
	- Treated water:	42 µg/L	
Iron:*	- Bourget well:	0.16 mg/L	* January data only
	- Infiltration gallery:	0.51 mg/L	
	- Treated water:	0.22 mg/L	
Manganese:*	- MOE well:	0.004 mg/L	* January data only
	- Bourget well:	0.01 mg/L	
	- Infiltration gallery:	0.12 mg/L	
	- Treated water:	0.03 mg/L	
THMs:	- Treated water:	255 to 326	273 µg/L
	- Distribution System:	216 to 360	295 µg/L
HAAs:*	- Treated water:	116 µg/L	* January data only
	- Distribution System:	104 µg/L	
Temperature:			
	- Collection Sump:		12 °C (summer)
		8 to 9 °C	9 °C (winter)

TABLE 3.1 BOURGET WATER TREATMENT PLANT
WATER QUALITY RESULTS - 1996
WATER SAMPLES ANALYZED BY THE MOE FOR THE DRINKING WATER SURVEILLANCE PROGRAM (DWSP)

	Jan-96	Feb-96	Apr-96	May-96	Jun-96	Jul-96	Dec-96	MINIMUM	MAXIMUM	AVERAGE
TURBIDITY - MOE WELL (NTU)	0.1	-	-	-	0.6	-	-	0.1	0.6	0.4
TURBIDITY - BOURGET WELL (NTU)	2.3	-	-	-	0.8	-	-	0.8	2.3	1.5
TURBIDITY - INFIL. GALLERY (NTU)	2.8	-	1.2	-	2.3	-	-	1.2	2.8	2.1
TURBIDITY - TREATED WATER (NTU)	1.8	-	-	1.1	1.0	1.1	1.5	1.0	1.8	1.3
COLOUR - MOE WELL (TCU)	39	38	-	-	38	-	-	38	39	38
COLOUR - BOURGET WELL (TCU)	41	39	-	-	37	-	-	37	41	39
COLOUR - INFIL. GALLERY (TCU)	13	15	19	-	8	-	-	8	19	14
COLOUR - TREATED WATER (TCU)	11	-	-	12	12	11	14	11	14	12
DOC - MOE WELL (mg/L)	5.5	5.6	-	-	5.8	-	-	5.5	5.8	5.6
DOC - BOURGET WELL (mg/L)	5.5	5.5	-	-	5.5	-	-	5.5	5.5	5.5
DOC - INFIL. GALLERY (mg/L)	2.4	3.4	4.3	-	2.9	-	-	2.4	4.3	3.3
DOC - TREATED WATER (mg/L)	4.6	-	-	4.7	4.9	4.2	4.5	4.2	4.9	4.6
SODIUM - INFIL. GALLERY (mg/L)	7.2	-	5.0	-	4.8	-	-	4.8	7.2	5.7
SODIUM - TREATED WATER (mg/L)	-	-	-	198.0	-	230.0	218.0	198.0	230.0	215.3
pH - MOE WELL	8.9	-	-	-	8.9	-	-	8.9	8.9	8.9
pH - BOURGET WELL	9.0	-	-	-	9.0	-	-	9.0	9.0	9.0
pH - INFIL. GALLERY	7.9	-	7.6	-	7.6	-	-	7.6	7.9	7.7
pH - TREATED WATER	7.7	-	-	-	8.7	8.7	8.8	7.7	8.8	8.5
ALKALINITY - MOE WELL (mg/L)	408	-	-	-	406	-	-	406	408	407
ALKALINITY - BOURGET WELL (mg/L)	359	-	-	-	362	-	-	359	362	361
ALKALINITY - INFIL. GALLERY (mg/L)	78	-	66	-	70	-	-	66	78	71
ALKALINITY - TREA. WATER (mg/L)	300	-	-	265	296	309	299	265	309	294
ALUMINUM - MOE WELL (ug/L)	2	-	-	-	-	-	-	-	-	-
ALUMINUM - BOURGET WELL (ug/L)	85	-	-	-	-	-	-	-	-	-
ALUMINUM - INFIL. GALLERY (ug/L)	100	-	-	-	-	-	-	-	-	-
ALUMINUM - TREATED WATER (ug/L)	42	-	-	-	-	-	-	-	-	-
IRON - BOURGET WELL (mg/L)	0.16	-	-	-	-	-	-	-	-	-
IRON - INFIL. GALLERY (mg/L)	0.51	-	-	-	-	-	-	-	-	-
IRON - TREATED WATER (mg/L)	0.22	-	-	-	-	-	-	-	-	-
MANGANESE - MOE WELL (mg/L)	0.004	-	-	-	-	-	-	-	-	-
MANGANESE - BOURGET WELL (mg/L)	0.01	-	-	-	-	-	-	-	-	-
MANGANESE - INFIL. GALLERY (mg/L)	0.12	-	-	-	-	-	-	-	-	-
MANGANESE - TREATED WATER (mg/L)	0.03	-	-	-	-	-	-	-	-	-
THMs - TREATED WATER (ug/L)	265	261	278	255	259	326	266	255	326	273
THMs - DISTRIBUTION SYSTEM (ug/L)	270	291	322	296	314	360	216	216	360	295
HAAs - TREATED WATER (ug/L)	116	-	-	-	-	-	-	-	-	-
HAAs - DISTRIBUTION SYSTEM (ug/L)	104	-	-	-	-	-	-	-	-	-

The Bourget groundwater supply has a relatively high chlorine demand meaning that larger amounts of chlorine are required to provide a persistent chlorine residual concentration in the distribution system. Some of the chlorine added for disinfection reacts chemically with the organics present in the water and produces THMs. The level of THMs in the treated water in 1996 varied from 255 to 326 µg/L for an average of 273 µg/L. The THMs level in the distribution system varied from 216 to 360 µg/L for an average of 295 µg/L. These results are exceeding the Ontario Drinking Water Objective (ODWO) of 100 µg/L.

The water samples taken for THMs analysis in the distribution system were quenched with sodium thiosulfate to remove chlorine residual to stop any further reaction between free chlorine and organics. Quenched water samples taken in the distribution system will maintain the same level of THMs as existed at the time of sampling, thereby representing the quality experienced by the consumer. The water samples taken for THMs analysis at the water treatment plant were not quenched, to stimulate the further contact time that would occur in the distribution system.

The levels of organic matter measured by dissolved organic carbon (DOC) analysis are relatively high for the Bourget groundwater supply. The average DOC concentration in the MOE well and the Bourget well is above 5 mg/L, and the average concentration in the infiltration gallery is 3.3 mg/L. The average DOC concentration in the treated water is 4.6 mg/L.

The average turbidities in the MOE and the Bourget wells are 0.4 and 1.5 NTU respectively. The highest levels are found in the infiltration gallery with turbidity ranging from 1.2 to 2.8 NTU for an average of 2.1 NTU. The turbidity in the treated water representing a mix of the three sources of raw water varied from 1.0 to 1.8 for an average of 1.3 NTU. This is above the ODWO of 1 NTU and exceeds the operational objective of this study of 0.1 NTU for protection against pathogen microorganisms. The MOE and the Bourget wells are deep wells therefore the presence of microorganisms such as cryptosporidium and giardia cysts is unlikely. However, the infiltration gallery which is a shallow well is under the influence of surface water and is susceptible to cysts contamination.

The colour in the MOE and the Bourget wells is high with an average of 38 and 39 TCU respectively. The colour in the infiltration gallery ranges from 8 to 19 TCU for an average of 14 TCU. The colour in the treated water ranges from 11 to 14 TCU for an average of 12 TCU. This is above the MOE guideline of 5 TCU. The colour level in the treated water is much lower than the colour from the MOE and the Bourget wells. This is due to bleaching from chlorine used for disinfection. Colour is an aesthetic and not a health related parameter, but high levels are indicative of the presence of organics which react with chlorine to form THMs.

Historical data presented in Table 3.1 for water samples collected in January 1996 indicates that the infiltration gallery contains the highest level of aluminum (100 µg/L). The concentration measured in the treated water is below the ODWO operational guideline of 100 µg/L with 42 µg/L.

Results also indicate that the sodium level in the treated water averages 215 mg/L. The MOE guideline for sodium level is 200 mg/L. Sodium concentration in the Bourget water supply is therefore above the level that would warrant a health advisory to persons on a sodium reduced diet. The groundwater quality in this region of the province, though meeting Ontario Drinking Water Objectives for minerals content, is generally high in sodium and chloride. Water sampling results for 1996 indicated that the level of chloride in the treated water ranged from 169 to 212 mg/L and did not exceed the ODWO of 250 mg/L.

Water samples collected in January 1996 indicated that a moderate level of iron was found in the infiltration gallery (0.51 mg/L), but the level in the treated water remained below the MOE guideline of 0.3 mg/L with a concentration of 0.22 mg/L. The sampling also indicated that a high level of manganese was found in the infiltration gallery (0.12 mg/L). The level in the treated water remained below the MOE guideline of 0.05 mg/L with a manganese concentration of 0.03 mg/L.

Analysis were performed to evaluate the level of haloacetic acids (HAAs) in the treated water. HAAs are by-products of disinfection with chlorine reacting with humic substances, and are of concern to human health. Currently, there is no guideline in Ontario regulating the maximum level of HAAs in drinking water. The US Environmental Protection Agency (USEPA) has proposed regulating five major HAAs in the upcoming Disinfectants/Disinfection By-products (D/DBP) Rule – monochloroacetic acid (MCAA), DCAA, TCAA, monobromoacetic acid (MBAA), and dibromoacetic acid (DBAA). In the first stage of the D/DBP Rule, the proposed maximum contaminant level is 60 μg/L for the total concentration of these five HAAs.

Samples were taken in the treated water at the plant and in the distribution system for HAAs analysis. The samples taken at the plant were unquenched and the samples in the distribution system were quenched with ammonium chloride to stop any further formation representing the quality experienced by the consumer. The level of HAAs in the treated water collected at the plant in January 1996 is 116 μg/L. HAAs concentrations in the distribution system was 104 μg/L. Additional samples would be required to confirm actual HAAs concentration in the treated water.

4.0 PERFORMANCE ASSESSMENT

4.1 DISINFECTION

Disinfection of drinking water is the most important aspect of the treatment process. Harmful organisms in water such as bacteria, viruses or cysts can cause illness ranging from minor intestinal disorders to potentially fatal infections. Maintaining an effective disinfection system must be the overriding priority of the plant operations. For water supply under the influence of surface waters, chlorination with a 'free' residual is the most common and most practical method of disinfection. To be effective, the treated water must be very low in turbidity as suspended particles can shield bacteria and virus from the effect of chlorine. Turbidity levels greater than 0.1 NTU indicate an increased probability of chlorine resistant cysts being present.

To achieve a safe level of disinfection, it is necessary to dose the treated water with a sufficient amount of chlorine to produce a 'free' residual, and to give the chlorine sufficient time to inactivate the potentially harmful organisms. This is called the concentration-time factor or CT, also referred to as the primary disinfection stage. Sufficient CT must be achieved at the treatment plant before the first service connection.

Current MOE guidelines call for a minimum residual of 0.5 mg/L for a minimum contact time of 30 minutes after filtration. This disinfection guideline for water treatment plants in Ontario is under review, and the new guideline may be similar to the Surface Water Treatment Rule (SWTR) promulgated by U.S. Environmental Protection Agency (U.S. EPA). The SWTR established CT values for chlorine, chlorine dioxide, ozone and chloramines required to achieve adequate inactivation of giardia cysts and viruses. For the purpose of calculating CT value, T is the time (in minutes) it takes the water, during peak plant flows, to move between the point of disinfectant application and a point where, C, residual disinfectant (in mg/L) concentration is measured just prior to the first customer. The calculation must take into account the degree of short circuiting in the storage tank.

For free residual chlorination, the CT required is based on the inactivation of giardia cysts in cold water. Giardia cysts are harder to inactivate by free chlorine than viruses, therefore, it is implied that proper inactivation of giardia cysts will ensure inactivation of viruses. Disinfection with chlorine is not effective for the inactivation of cryptosporidium.

Secondary disinfection refers to the maintenance of a residual in the distribution system to protect against bacterial re-growth or minor cross connection contamination. This maintenance residual is commonly achieved with 'free' chlorine, but alternatively can be converted to chloramine or 'combined' residual with the addition of ammonia. Chloramines have the advantage of being more stable and lasting much longer in the system. They also do not react with organics to form THMs. They are however much less effective as a disinfectant and are very weak in inactivating viruses and cysts. Use of chloramine as a primary disinfectant is therefore not recommended.

The MOE guidelines recommend maintenance of a free chlorine residual at the end of the distribution system. The AWWA recommends a minimum residual of 1.0 mg/L of chloramine be maintained when chloramination is practical, to prevent re-growth (AWWA, 1993).

Based on the "Guidance Manual for Compliance With the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Source" (U.S. EPA, 1990), when a tracer study is not available, the short circuiting condition in the storage tank expressed as T_{10}/T factor can be evaluated to estimate the effective contact time in the elevated tank. This factor represents the ratio between T_{10}, which is the time it takes 10 percent of a dye or tracer to pass through the basin outlet after it is injected into the basin influent flow, and the theoretical detention time for plug flow in pipelines and flow in a completely mix chamber.

The elevated tank has a working volume of 750 m^3. A 75 mm (3") nozzle was installed in December 1997 at the end of the storage tank inlet pipe on top of the tank to induce a rotation of the water in storage and reduce short circuiting to the outlet, and therefore increase the chlorine contact time. The previous inlet discharged near the top of the tank without a nozzle. It is estimated that this improved the short circuiting factor (T_{10}/T) to 0.5.

The evaluation of minimum residual chlorine concentration required for inactivation of giardia cysts for an average raw water temperature of 10 °C is presented in Appendix A. A short circuiting factor T_{10}/T of 0.5 was used for the calculations representing the new condition in the storage tank after installation of a 75 mm nozzle to induce spiral flow. The pH of the raw water used for the calculations was 8.5. This parameter remains relatively constant through the year. The CT calculations were done under the most critical condition when the storage tank is half full for the summer maximum day demand (300 m^3/d). The minimum free chlorine residual required for inactivation of giardia cysts is 0.2 mg/L for an estimated contact time in the storage tank of 900 minutes (15 hours).

Preliminary results indicate that with a free chlorine residual in the re-circulating system of 0.3 to 0.4 mg/L, the levels of THMs vary from 50 to 80 µg/L during the winter and from 80 to 120 µg/L during the summer. However, THMs will continue to form in the distribution system with a free chlorine residual.

In addition to the disinfection requirement, there is a need to ensure sufficient chlorine residual to protect the distribution system against re-growth or external contamination. If the chlorine residual declines in the distribution system this would result in the development of biological growth that is very difficult to remove once established. To avoid further production of THMs in the distribution system and still maintain a chlorine residual, it is recommended to perform chloramination of the treated water leaving the high lift pumps.

It is recommended to install a second injection point for sodium hypochlorite at the high lift pumps header to increase the free chlorine residual to 2 mg/L, and to combine it with ammonium sulphate to maintain a combined chlorine residual of approximately 2 mg/L leaving the booster pumps building.

Studies in the United States have indicated that municipalities that maintain a residual of 2.0 mg/L of combined chlorine do not experience nitrification. Where residuals are less than 2.0 mg/L there is a greater risk of nitrification leading to biological growth in the distribution system. The amount of risk depends heavily on the chlorine to ammonia ratio and the water temperature. The lower the ratio of Cl_2 to NH_3-N the more excess ammonia there will be and hence more nutrient for the nitrifying bacteria. Also the higher the water temperature the greater the growth rate of bacteria.

5.0 CONCLUSIONS

Since the Bourget water supply system does not include treatment units such as flocculation tanks, clarifiers or sand filters but only performs disinfection with chlorine, it is not feasible to improve further the quality of the treated water regarding colour, turbidity, and sodium levels which are above the ODWO guidelines.

The turbidity in the treated water representing a mix of the three sources of raw water varied from 1.0 to 1.8 for an average of 1.3 NTU. This is above the ODWO of 1 NTU and significantly exceeds the objective of this study of 0.1 NTU for protection against pathogen microorganisms. The MOE and the Bourget wells are deep therefore the presence of microorganisms such as cryptosporidium and giardia cysts is unlikely. However the shallow well which is essentially an infiltration gallery is under the influence of surface water and is susceptible to cysts and other contamination. Care should be taken on the types of activities over this collection area particularly with use of pesticides and fertilizers.

Laboratory work with samples of water from the supply sources used at Bourget was conducted to evaluate the impact of disinfecting the water with chlorine dioxide. It was expected that like chlorine, chlorine dioxide (ClO_2) will produce some bleaching of the water to reduce the colour and maintain a low level of THMs in the treated water since chlorine dioxide does not react with organics to form THMs.

Preliminary testing failed to provide a chlorine dioxide residual, and by-products concentrations such as chlorite were too high. Considering these issues, using chlorine dioxide for disinfection was not evaluated further. Further work concentrated on how to reduce the recirculation system and storage tank short circuiting to allow a reduction in the free chlorine residual in the storage tank and therefore THMs formation, while maintaining disinfection with a chlorine residual in the distribution system.

6.0 RECOMMENDATIONS

The recommendations made to improve the disinfection efficiency and to reduce the levels of THMs for the Bourget water supply system are summarized as follows:

- Improve the chlorine contact time in the storage tank.
- Perform chloramination of the treated water entering the distribution system.
- Investigate an alternative treatment process.

6.1 IMPROVEMENT OF CHLORINE CONTACT TIME IN THE STORAGE TANK

A 75 mm (3") nozzle was installed in December 1997 at the end of the storage tank inlet pipe to induce a rotation of the water in storage and reduce short circuiting to the outlet, and therefore increase the chlorine contact time. The previous inlet discharged near the top of the tank without a nozzle. The installation of baffles in the recirculation tank to improve the contact time would be very difficult and expensive.

6.2 CHLORAMINATION

Ammonia injection for post-chloramination in the distribution system was found to be desirable and required an amendment to the current Certificate of Approval. The C of A for the chloramination system has been issued and a copy is presented in Appendix B. Changing the disinfectant to chloramine for the water leaving the high lift pumps was recommended to maintain a chlorine residual in the distribution system and to reduce THMs formation. Preliminary testing showed that chloramination alone would not lower the high colour level in the treated water nor would it provide adequate disinfection for virus. A free chlorine residual must be maintained in the storage tank for these purposes.

Ammonia combines chemically with chlorine to produce chloramine. Use of chloramine has two consequences relevant to drinking water quality. These are as follows:

1. Chloramine does not react with organics present in the water to form THMs.
2. Chloramine is a less powerful disinfectant than chlorine and care must be taken to ensure this factor does not affect water quality.

Chloramine alone is generally not considered powerful enough for surface water disinfection even when used for many hours at high concentrations. The AWWA recommends a minimum residual of 1.0 mg/L of chloramine be maintained in the distribution system to prevent re-growth (AWWA, 1993). Addition of sodium hypochlorite at the high lift pump header should be performed to a recommended free chlorine residual of 2 mg/L, in combination with the addition of ammonium sulphate to maintain a combine and chlorine residual or chloramine level leaving the high lift (booster) pump building of 2 mg/L.

Ammonia can be supplied as a compressed liquefied or saturated solution, a gas form, or in dry compounds. Ammonia gas is toxic and corrosive, and handling the concentrated solution requires refrigeration. Consequently, ammonium sulphate in dry compound is preferred. Ammonium sulphate is a free flowing crystalline water soluble salt which is not strongly toxic. When required, the ammonium sulphate solution should be prepared at least weekly. This solution is added at a controlled dosage in the high lift pump header to achieve a chlorine to ammonia ratio of 3:1 to 5:1.

This treatment has proved satisfactory and is expected to produce THMs levels in the distribution system around 80 to 120 µg/L during the summer and 50 to 80 µg/L during the winter when maintaining a free chlorine residual in the elevated tank of 0.3 to 0.4 mg/L. The THMs level during the summer may at times exceed the ODWO of 100 µg/L but will be considerably improved compared to the high value recorded of 500 µg/L. The switch to post-chloramination was implemented in the spring of 1998.

Dosage of Ammonium Sulphate

The procedure adopted for determining the dosage of ammonium sulphate required is as follows:

- Check the concentration of free and total chlorine residual in the high lift pump header immediately after injection of sodium hypochlorite.
- Adjust chlorine feed to give a free chlorine residual of 2 mg/L at this point.
- Adjust the ammonium sulphate feed to give a combine chlorine residual of 2 mg/L.
- The preparation of the ammonium sulphate solution for a 7 day supply is described in Appendix C.

6.3 ALTERNATIVE TREATMENT PROCESS

Additional investigation could be undertaken to evaluate the feasibility of using air stripping to bring down the level of THMs from a maximum of 500 µg/L to 100 µg/L. The construction of a treatment plant with coagulation, flocculation, sedimentation, filtration or membrane filtration, and disinfection would be required to meet the MOE Guidelines for colour, turbidity and THMs with the shallow well source of water supply due to the potential for the contamination from surface runoff.

It is also recommended to investigate additional deep well supplies to replace the infiltration well to reduce the risk of pathogenic organisms entering the water supply.

7.0 COSTS ESTIMATE FOR IMPLEMENTATIONS

The implementation of post-chloramination to reduce the level of THMs in the treated water involved the purchase of two day tanks and one mixer for a total cost of approximately $1,200. This cost was assumed by the MOE. The two dosing pumps required for the second injection point of sodium hypochlorite and for dosing ammonium sulphate were already available at the plant.

The installation of the 75 mm nozzle at the end of the storage tank inlet pipe to induce a rotation of the water in storage and reduce short circuiting to the outlet was done by the Town in the winter of 1997.

The additional operating cost related to dosing ammonium sulphate could not be estimated accurately since the exact dosage required was not known. However, it is estimated that the additional chemical costs will not be considerable.

GLOSSARY AND LIST OF ABBREVIATIONS

Alum	: aluminum sulphate
CT	: Value required to achieve adequate inactivation and/or removal of cysts and viruses. T is the time (in minutes) it takes the water during peak hourly flow, to move between the point of disinfectant and a point where C, the residual disinfectant concentration (mg/L), is measured prior to the first customer.
d	: day
°C	: degree Celsius
DWSP	: Drinking Water Surveillance Program
ECR reagent	: Eriochrome Cyanine R
FID	: Flame Ionization Detector
ft	: foot
G	: flocculation energy gradient
Gt	: flocculation energy
GC/MS	: Gas Chromatograph / Mass Spectrometry
GAC	: Granular Activated Carbon
g	: gram
h	: hour
HFS	: hydroxylated ferric sulphate (Ferriclear)
ICP	: Inductively Coupled Plasma Atomic Emission Spectoscopy
IG	: imperial gallon
kW	: kilowatt
L	: litre
L/cap.d	: litres per capita per day
L/s	: litres per second
m	: metre
m^2	: square metres
m^3	: cubic metres

m^3/d	: cubic metres per day
m/h	: metres per hour (equivalent $m^3/m^2.h$ - filtration rate)
µg/L	: micrograms per litre
mg/L	: milligrams per litre
mm	: millimetre
mL/min	: millilitres per minute
min	: minute
NTU	: Nephelometric Turbidity Unit
OCWA	: Ontario Clean Water Agency
ODWO	: Ontario Drinking Water Objective
%	: percent
PACL	: polyaluminum chloride
PVC	: polyvinyl chloride
lb	: pound
rpm	: revolution per minute
SOR	: Surface Overflow Rate
SWTR	: Surface Water Treatment Rule
T_{10}/T	: This factor describes the baffling condition in the clearwell, and represents the ratio between T_{10}, which is the time it takes 10 percent of a dye or tracer to be detected at the basin outlet after it is injected into the basin influent flow, and the theoretical detention time for plug flow in pipelines and flow in a completely mixed chamber.
TOC	: Total Organic Carbon
THMs	: Trihalomethanes
TCU	: True Colour Unit
W/V	: weight/volume

REFERENCES

American Water Works Association Research Foundation - Optimizing Chloramine Treatment, 1993.

Environmental Science and Engineering Magazine. Drinking water Update - The Facts About Human Health and Aluminum in Drinking Water, January, 1997.

U.S. Environmental Protection Agency, Science and Technology Branch Criteria and Standards Division of Drinking Water. Guidance Manual for Compliance With the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources, October , 1990.

Ontario Ministry of the Environment, Environmental Approvals and Land Use Planning Branch. Guidelines for the Design of Water Treatment Works, April 1982.

APPENDICES

Evaluation of Residual Chlorine Concentration for Inactivation of Giardia Cysts

Appendix A

A.1 BOURGET WATER TREATMENT PLANT

Evaluation of residual chlorine concentration required for 3-log inactivation of giardia cysts for the elevaled tank 50% full, and water temperature of 10 °C:

NOTES:

* The SWTR establishes CTs for chlorine, chlorine dioxide, ozone and chloramines which will achieve a min. of 3-log inactivation of giardia cysts.

CT for 3.0-log inactivation = 177 (at 10 °C, pH=8.5 and Conc. <= 0.4 mg/L)

Where C = Concentration (mg/L)
T = Contact Time (min)

Evaluation of contact time (T):

T= [Volume of Clearwell (m^3) x %Full x Baffling Condition (T_{10}/T)] / [Maximum Day Flow (m^3/d)] x 1,440 min/d

Volume of El. Tank =	750 m^3
% Full =	0.5
T_{10}/T =	0.5
Max. Day Flow =	300 m^3/d
Temperature =	10 °C

T = 900 Minutes

Evaluation of Residual Chlorine Concentration (C):

C = CT for 3.0-log inactivation / T
CT = 177

C = 0.20 mg/L

C of A for Chloramination System

Appendix B

Ontario

Ministry of Environment and Energy

Ministère de l'Environnement et de l'Énergie

CERTIFICATE OF APPROVAL
WATER
NUMBER 7-0492-94-95(

Corporation of the Township of Clarence
P.O. Box 70, 415 Lemay Street
Clarence Creek, Ontario
K0A 1N0

You have applied in accordance with Section 52 of the Ontario Water Resources Act for approval of:

modifications to the existing groundwater supply works, located on Lot 18, Concession 5, in the Township of Clarence, serving the Village of Bourget, consisting of the following:

- upgrading and replacement of control systems, comprising supply and installation of:
  - programmable control units, terminals, uninterruptable power supplies and associated accessories at the existing pump house and booster pump station;
  - new pump and level controllers and a continuous chlorine residual analyzer at the pump house;
  - ultrasonic level sensors at the existing potable water storage tank and raw water collection chamber;
- supply and installation of a new chlorination system at the existing booster pump station, comprising:
  - a 450 litre capacity sodium hypochlorite solution storage tank;
  - two (2) chemical metering pumps (one duty, one standby), together with associated controls, injection piping, appurtenances and continuous chlorine residual analyzer to provide demand-based automatic chlorine dosing, feeding into the new recirculation line leading to the existing pump house;
- supply and installation of a recirculation pump system at the existing booster pump station, comprising two (2) in-line type, centrifugal circulator pumps (one duty, one standby), each pump rated at 7.6 L/s (120 USgpm) at approx. 6m (20 feet) TDH, together with associated controls, valves, appurtenances and 100mm dia. recirculation piping from the booster pump station to the pump house;
- decommissioning and removal of the existing hypochlorination system at the pump house;
- supply and installation of a pressure control system for the existing booster pumps, and any appurtenances and modifications as required by the existing Bourget groundwater supply works;

all in accordance with the Application for Approval dated June 6, 1994, final plans and specifications, the revised "Design Report Township of Clarence, Village of Bourget, Improvements to Control and Disinfection Systems", dated July 8, 1994 and supplementary data and letters dated July 26 and November 14, 1994, all as prepared by Kostuch Engineering Limited, Consulting Engineers.

You are hereby notified that this approval is issued subject to the terms and conditions outlined below:

TERMS AND CONDITIONS

1. For the purpose of this Certificate of Approval:

   (a) "Director" means any Ministry employee within the Ministry appointed by the Minister pursuant to section 5 of the *Ontario Water Resources Act*;

   (b) "Ministry" means the Ontario Ministry of Environment and Energy;

   (c) "the Regional Director" means the Regional Director of the Eastern Region of the Ministry;

   (d) "the District Manager" means the District Manager of the Cornwall District Office of the Ministry's Eastern Ontario Region;

   (e) "Owner" and "Operating Authority" means Corporation of the Township of Clarence and includes its successors and assignees;

   (f) "works" means the facilities described in the Owner's application, the Certificate and in the supporting documentation referred to herein, to the extent approved by this Certificate;

   (g) "the water supply and treatment system" means the works and auxiliaries for collection, treatment, storage and distribution of the water from the source of supply to free flowing outlet of the ultimate consumer;

2. The approval granted by this Certificate is based upon a review of the proposed works in the context of its effect on the environment, its process performance and principles of sanitary engineering.

   The review did not include a consideration of the architectural, mechanical, structural, electrical or instrumentational components of the works except to the extent necessary to review the works as set out in the above paragraph.

3. The requirements of this Certificate of Approval are imposed pursuant to Section 52 of the *Ontario Water Resources Act*. The issuance of this Certificate in no way abrogates the Owner's legal obligations to take all reasonable steps to avoid violating other applicable provisions of this legislation and other legislations and regulations.

4. a. The requirements of this Certificate are severable. If any requirement of this Certificate, or the application of any requirement of this Certificate to any circumstances, is held invalid, the application of such requirement to other circumstances and the remainder of this Certificate shall not be affected thereby.

   b. In all matters requiring the interpretation and implementation of this Certificate, the conditions of the Certificate shall take precedence, followed in descending order by the Owner's application and the documentation, referred to in this Certificate, which is submitted in support of the application.

5. The Owner must ensure compliance with all the terms and conditions of this Certificate. Non-compliance constitutes a violation of the *Ontario Water Resources Act* and is grounds for enforcement.

6. The Owner shall, forthwith upon the request of the Director, Regional Director or District Manager, furnish any information requested concerning compliance with this Certificate including any records required to be kept by this Certificate.

7. a. The Owner shall prepare and make available for inspection by Ministry personnel upon request, a complete set of drawings within one (1) year of substantial completion of the water works which drawings shall show the water works as constructed at that time.

   b. A complete set of the "as constructed" drawings, incorporating any amendments made from time to time, shall be kept by the Owner at the administration building of the water works as long as the water works are kept in operation.

OPERATIONS AND MAINTENANCE

8. a. The Owner shall endeavour to take all necessary steps, within his authority, to ensure protection of the source of water supply (ground water aquifer and infiltration galleries) from contamination.

   b. Subsequent to construction of, or repairs to the works, and prior to utilization of the works for the supply of potable water, the Owner shall ensure that the works have been adequately disinfected in accordance with the Ministry of Environment and Energy Bulletin 65-W-4 latest edition requirements as a minimum.

c. The Owner shall ensure that, at all times, the water works and related equipment and appurtenances which are installed or used to achieve compliance with this Certificate are properly operated and maintained. Proper operation and maintenance includes effective performance, adequate funding, adequate operator staffing and training, adequate laboratory and process controls, and the use of process chemicals and other substances that come in contact with water being treated, that are suitable for the process, compatible with each other and appropriate for drinking water.

d. The Owner shall ensure that prior to commissioning of the water works, contingency plans and procedures are established and adequate equipment and material are available for dealing with emergencies, upset conditions and equipment breakdowns in the water works.

e. The Owner shall establish notification procedures to be used to contact the District Manager and other relevant authorities in the case of an emergency.

PERFORMANCE

9. The Owner shall operate the entire water supply and treatment system in such a manner, and with such facilities that water supplied to the consumers serviced by the system satisfies the water quality objectives, guidelines and requirements as set out in the publication entitled "Ontario Drinking Water Objectives" 1983, as amended from time to time by more recently published editions.

10. a. The Owner shall construct the chlorination system in such a manner and with such facilities that the requirements set out in subsection (b) and (c) below can be satisfied.

b. The Owner shall operate the chlorination system in such a manner and with such facilities that a minimum of 0.2 mg/L of total chlorine residual in the treated water after minimum 15 minutes contact time and before the first consumer, is maintained at all times.

c. In case of identification of poor bacteriological water quality as defined in the "Ontario Drinking Water Objectives" or as directed by the District Manager, the Owner shall operate the chlorination system in such a manner and with such facilities that a minimum of 0.5 mg/L of total chlorine residual in the treated water after minimum 15 minutes contact time, and before the first consumer, is maintained at all times.

d. The Owner shall notify the District Manager and the Medical Officer of Health forthwith in the event that unchlorinated water is directed to the distribution system.

The reasons for the imposition of these terms and conditions are as follows:

1. Condition No. 1 is included to define terms used in this Certificate of Approval.

2. Condition No. 2 is included to make the owner, subsequent owners, successors, assignees, and any third parties relying upon the certificate, aware that the review conducted by this Ministry and the approval granted as a result is limited in scope and should not be relied upon as an approval of the stipulated design aspects of the works.

3. Condition No. 3 is included to emphasize that the issuance of the Certificate does not diminish any other statutory and regulatory obligation to which the Owner is subject in the construction, maintenance and operation of the works.

4. Condition No. 4 is included to clarify how the Certificate is to be judicially interpreted and specifically, to clarify that the requirements of the Certificate are severable and that they prevail over supporting documentation.

5. Condition No. 5 is included to emphasize that the Owner is under a statutory obligation to ensure compliance with the Certificate.

6. Condition No. 6 is included to ensure that Ministry personnel, when acting in the course of their duties, will be given unobstructed access to the facilities, information and records related to the works which are the subject of this Certificate. In addition, Condition No. 6 is included to enable the Ministry to be assured of the Owner's compliance with the terms and conditions of this Certificate.

7. Condition No. 7 is included to ensure that the Ministry records can be kept accurate and current with respect to approved works.

8. Condition No. 8 is included to ensure that the works will be operated, maintained, funded, staffed and equipped in a manner enabling compliance with the terms and conditions of this Certificate and that the Owner can deal with contingency and/or emergency situations.

9. Condition Nos. 9 and 10 are included to ensure that the water quality delivered by the works satisfies the current "Ontario Drinking Water Objectives" in order to protect public health and to ensure that the water is aesthetically acceptable.

You may by written notice served upon me and the Environmental Appeal Board within 15 days after receipt of this Notice, require a hearing by the Board. Section 101 of the Ontario Water Resources Act, R.S.O. 1990, Chapter 0.40, provides that the Notice requiring the hearing shall state:

1. The portions of the approval or each term or condition in the approval in respect of which the hearing is required, and;
2. The grounds on which you intend to rely at the hearing in relation to each portion appealed.

The Notice should also include:

3. The name of the appellant;
4. The address of the appellant;
5. The Certificate of Approval number;
6. The date of the Certificate of Approval;
7. The name of the Director;
8. The municipality within which the water works are located;

And the Notice should be signed and dated by the appellant.

This Notice must be served upon:

The Secretary,
Environmental Appeal Board,
112 St. Clair Avenue West,
Suite 502,
Toronto, Ontario.
M4V 1N3

AND

The Director,
Section 52, Ontario Water Resources Act,
Ministry of Environment and Energy,
250 Davisville Avenue, 3rd Floor,
Toronto, Ontario.
M4S 1H2

The above noted water works are approved under Section 52 of the Ontario Water Resources Act.

DATED AT TORONTO this 4th *day of* January, 1995

THIS IS A TRUE COPY OF
THE ORIGINAL CERTIFICATE
SIGNED BY
D.F. CARR, P. ENG.

MAILED ON JAN 0 4 1995

BY _____

HS/fn

Attn: Mr. R. Lalonde, Clerk, Township of Clarence
cc: District Manager, MOEE Cornwall District Office
Mr. J.C. Johnston, P. Eng., Kostuch Engineering Ltd.
D. Henry, MOEE Sc. & Tech. Branch, (via K. Roberts Environmental, Monitoring & Reporting Branch)

NOTICE

Township of Clarence
415 Lemay Street
Clarence Creek, Ontario
K0A 1N0

You are hereby notified that the Certificate of Approval No. 7-0492-94-956, issued on January 4, 1995 for the upgrading to the water supply and distribution system serving the community of Bourget in the Township of Clarence, including replacement of the existing chlorination, is hereby amended to approve temporary modifications to the approved and now existing works, as follows:

experimental installation of a trihalomethane (THM) generation control colour removal and disinfection system utilizing on site generated chlorine dioxide solution, temporarily replacing the existing chlorination system utilizing sodium hypochlorite solution, with the sodium hypochlorite system remaining on stand-by during the experiment, consisting of the following:

- an electrochemical chlorine dioxide generator rated at a ClO_2 production of 1.0 kg per day, utilizing sodium chlorite solution as feedstock and producing sodium hydroxide and some hydrogen gas as by products, installed in the existing Booster Water Pumping Station located on lot 18, Concession 5, in the Township of Clarence, together with two (2) eductors utilizing the supply watermain pressure to draw sodium chlorite solution from a 200 litre capacity sodium chlorite solution storage tank through the generator and discharging the generated chlorine dioxide solution into the below-described chlorine dioxide solution storage tank and the by-product solution into the below-described waste stream holding tank;

- a 140 litre capacity chlorine dioxide solution storage tank, together with one (1) chemical metering pump and a solution feed line to the existing stored water recirculation loop down-stream of the recirculation pumps within the booster pumping station; and

- a 200 litre capacity chlorine dioxide generation waste stream holding tank for periodical batch neutralization of the collected sodium hydroxide solution using dry sodium bisulphate, and discharge of the resulting week solution of sodium sulphate into the existing drainage ditch adjacent to the booster pumping station;

all in accordance with the application for approval dated July 29, 1997.

You are hereby notified that the approval granted by this Notice is subject to the following terms and conditions:

TERMS AND CONDITIONS

1. This Notice shall expire, and become null and void, on December 1, 1997.

2. The pH level of the neutralized chlorine dioxide generator waste stream proposed to be discharged to the local drainage ditch shall be maintained within the range of 6.5 to 8.5 during all discharges.

REASONS FOR TERMS AND CONDITION

1. Condition No. 1 has been included to ensure that the proposed equipment is installed and used for the purpose of the proposed experiment only, and will not become a permanent part of the system unless so approved by the Director.

2. Condition No. 2 has been included to ensure that the proposed discharge of the waste stream will have no deleterious effect on the environment or its users.

This Notice shall constitute part of the approval issued under Certificate of Approval No. 7-0492-94-956 dated January 4, 1995.

In accordance with Section 100 of the Ontario Water Resources Act, R.S.O. 1990, Chapter 0.40, as amended, you may by written notice served upon me and the Environmental Appeal Board within 15 days after receipt of this Notice, require a hearing by the Board. Section 101 of the Ontario Water Resources Act, provides that the Notice requiring the hearing shall state:

1. The portions of the approval or each term or condition in the approval in respect of which the hearing is required, and;
2. The grounds on which you intend to rely at the hearing in relation to each portion appealed.

The Notice should also include:

3. The name of the appellant;
4. The address of the appellant;
5. The Certificate of Approval number;
6. The date of the Certificate of Approval;
7. The name of the Director;
8. The municipality within which the water works are located;

And the Notice should be signed and dated by the appellant.

This Notice must be served upon:

The Secretary,
Environmental Appeal Board,
2300 Yonge Street, 12th Floor,
P.O. Box 2382,
Toronto, Ontario.
M4P 1E4

AND

The Director,
Section 52, *Ontario Water Resources Act*,
Ministry of Environment and Energy,
250 Davisville Avenue, 3rd Floor,
Toronto, Ontario.
M4S 1H2

The above noted water works are approved under Section 52 of the Ontario Water Resources Act.

DATED AT TORONTO this 21st *day of* August, 1997.

THIS IS A TRUE COPY OF THE ORIGINAL SIGNED
ON Aug 22/97
SIGNED

M. Dhalla, P.Eng.,
Director,
Section 52,
Ontario Water Resources Act.

MTY/st

Attn: Ms. L. Richard, Clerk, Township of Clarence
cc: District Manager, MOEE Kingston District Office
Dr. A. Edmonds, MOEE Standards Development Branch (Plant Optimization)

NOTICE

TOWNSHIP OF CLARENCE
415 Lemay Street
Clarence Creek, Ontario
K0A 1N0

You are hereby notified that the Certificate of Approval No. 7-0492-94-956, issued on January 4, 1995 for the upgrading to the water supply and distribution system serving the community of Bourget in the Township of Clarence, including replacement of the existing chlorination, is hereby amended to approve temporary modifications to the approved and now existing works, as follows:

experimental installation of a **trihalomethane (THM) generation control colour removal and disinfection system** utilizing on site generated chlorine dioxide solution, temporarily replacing the existing chlorination system utilizing sodium hypochlorite solution, with the sodium hypochlorite system remaining on stand-by during the experiment, consisting of the following:

- a **chlorine dioxide generating system** rated at 68 kg of chlorine dioxide per day, utilizing solutions of sodium chlorite , sodium hypochlorite and hydrochloric acid as feedstock supplied in 200 L capacity drums, installed in the existing Booster Water Pumping Station located on lot 18, Concession 5, in the Township o Clarence, consisting of a reactor column with an eductor utilizing the supply watermain pressure to draw the feedstock chemical solutions from the supply drums through the reactor column, and discharge the generated chlorine dioxide solution into the below-described chlorine dioxide solution storage tank;

- a 400 litre capacity chlorine dioxide solution storage tank, together with one (1) chemical metering pump and a solution feed line to the existing stored water recirculation loop down-stream of the recirculation pumps within the booster pumping station;

all in accordance with the application for approval and supporting documentation dated July 29, 1997, and a revised proposal dated September 4, 1997.

You are hereby further notified that the approval granted by this Notice is subject to the following terms and conditions:

Terms and Conditions

1. This Notice shall expire, and become null and void, on December 1, 1997.

Reasons for the Amendment and Terms and Condition

This amendment to the Certificate is being issued to approve the proposed temporary installation and operation of equipment for experimental use of chlorine dioxide for water disinfection. The reasons for the conditions imposed on this approval are as follows:

1. Condition 1 has been included to ensure that the proposed equipment is installed and used for the purpose of the proposed experiment only, and will not become a permanent part of the system unless so approved by the Director.

This Notice shall constitute part of the approval issued under Certificate of Approval No. 7-0492-94-956 dated January 4, 1995, and shall revoke and replace the Notice issued on August 21, 1997.

In accordance with Section 100 of the Ontario Water Resources Act, R.S.O. 1990, Chapter 0.40, as amended, you may by written notice served upon me and the Environmental Appeal Board within 15 days after receipt of this Notice, require a hearing by the Board. Section 101 of the Ontario Water Resources Act, provides that the Notice requiring the hearing shall state:

1. The portions of the approval or each term or condition in the approval in respect of which the hearing is required, and;
2. The grounds on which you intend to rely at the hearing in relation to each portion appealed.

The Notice should also include:

3. The name of the appellant;
4. The address of the appellant;
5. The Certificate of Approval number;
6. The date of the Certificate of Approval;
7. The name of the Director;
8. The municipality within which the water works are located;

And the Notice should be signed and dated by the appellant.

This Notice must be served upon:

The Secretary,
Environmental Appeal Board,
2300 Yonge Street, 12th Floor,
P.O. Box 2382,
Toronto, Ontario.
M4P 1E4

AND

The Director,
Section 52, *Ontario Water Resources Act*,
Ministry of Environment and Energy,
250 Davisville Avenue, 3rd Floor,
Toronto, Ontario.
M4S 1H2

The above noted water works are approved under Section 52 of the Ontario Water Resources Act.

DATED AT TORONTO this 12th *day of* September, 1997.

ORIGINAL
ON Sept. 12, 1997
T.M.
(Signed)

for M. Dhalla, P.Eng.,
Director,
Section 52,
Ontario Water Resources Act.

MT/tm

cc:-Ms. L. Richard, Clerk, Township of Clarence
-District Manager, MOEE Kingston District Office
-Dr. A. Edmonds, MOEE Standards Development Branch (Plant Optimization)
-A. Gonthier, McNeely Engineering

Ontario

NOTICE

Township of Clarence
415 Lemay Street
Clarence Creek, Ontario
K0A 1N0

You are hereby notified that the Certificate of Approval No. 7-0492-94-956, issued on January , 1995, for the upgrading to the water supply and distribution system serving the community of Bourget in he Township of Clarence, including replacement of the existing chlorination system, is hereby amended to pprove temporary modifications to the approved and now existing works, as follows:

xperimental modifications to the existing colour removal and disinfection ystem utilizing sodium hypochlorite solution intended to reduce formation rihalomethanes in the process of chlorination, as follows:

installation of a tangentially oriented nozzle on discharge of the flow recirculation stream into the system's elevated water storage (chlorine contact) tank intended to reduce flow short circuiting in the tank so that the increased actual chlorine contact time would allow for reduced chlorine concentration in the tank; and

installation of a 200 litre capacity ammonium sulphate solution storage tank, together with one (1) chemical metering pump and a solution feed line to the existing booster pump header within the booster pumping station, to be operated together with the existing post-chlorination system feeding sodium hypochlorite solution into the same pump header, intended to accomplish chloramination of the water pumped to the distribution system;

ll in accordance with the application for approval and supporting ocumentation dated December 10, 1997.

You are hereby further notified that the approval granted by this Notice is subject to the llowing terms and conditions:

ERMS AND CONDITIONS

. This Notice shall expire, and become null and void, on June 1, 1998.

REASONS FOR THE AMENDMENT AND TERMS AND CONDITION

This amendment to the Certificate is being issued to approve the proposed temporary experimental modifications to the existing colour removal and disinfection system intended to reduce formation of trihalomethanes in the process of colour removal and disinfection, and within the water distribution system while maintaining an adequate level of chlorine residual in the distribution system to prevent secondary bacterial contamination. The reasons for the conditions imposed on this approval are as follows:

1. Condition No. 1 has been included to ensure that the proposed equipment is installed and used for the purpose of the proposed experiment only, and will not become a permanent part of the system unless so approved by the Director.

This Notice shall constitute part of the approval issued under Certificate of Approval No. 7-0492-94-956 dated January 4, 1995.

In accordance with Section 100 of the Ontario Water Resources Act, R.S.O. 1990, Chapter 0.40, as amended, you may by written notice served upon me and the Environmental Appeal Board within 15 days after receipt of this Notice, require a hearing by the Board. Section 101 of the Ontario Water Resources Act, provides that the Notice requiring the hearing shall state:

1. The portions of the approval or each term or condition in the approval in respect of which the hearing is required, and;
2. The grounds on which you intend to rely at the hearing in relation to each portion appealed.

The Notice should also include:

3. The name of the appellant;
4. The address of the appellant;
5. The Certificate of Approval number;
6. The date of the Certificate of Approval;
7. The name of the Director;
8. The municipality within which the water works are located;

And the Notice should be signed and dated by the appellant.

This Notice must be served upon:

The Secretary,
Environmental Appeal Board,
2300 Yonge Street, 12th Floor,
P.O. Box 2382,
Toronto, Ontario.
M4P 1E4

AND

The Director,
Section 52, *Ontario Water Resources Act*,
Ministry of the Environment,
250 Davisville Avenue, 3rd Floor,
Toronto, Ontario.
M4S 1H2

The above noted water works are approved under Section 52 of the Ontario Water Resources Act.

DATED AT TORONTO this 22nd *day of* December, 1997.

THIS IS A TRUE COPY OF THE
ORIGINAL SIGNED
ON Dec 23/97
SIGNED

M. Dhalla, P.Eng.,
Director,
Section 52,
Ontario Water Resources Act.

MT/st

Attn:-Ms. L. Richard, Clerk, Township of Clarence
cc: -District Manager, MOE Kingston District Office
-Dr. A. Edmonds, MOE Science & Technology Branch
-Mr. A. Gonthier, McNeely Engineering

Operating Procedures

Appendix C

C.1 Chlorine Level Checks

Water samples must be taken with the water system running for few hours to measure the free chlorine residual in the storage tank, and the free and total chlorine leaving the high lift pumps for the distribution system. Samples taken from the storage tank may respond slowly to chlorine change due to the relatively high contact time in the tank.

When sampling, make sure the sample bottle is glass and is completely filled with no air space under the cover. Allow the sample to stand for 30 minutes and then measure total and free chlorine using the DPD procedure with the DR7OO or DR2000.

C.2 Ammonium Sulphate Feed

Chlorine to Ammonia Ratio of 3:1

Dosage

- For every 1 mg/L of free chlorine, 0.62 mg/L of ammonium sulphate is added.

Solution

- For a 200 L tank (approximately 1 week supply of solution).
- Add 0.5 kg of ammonium sulphate to 100 L of water to get a 0.5 % solution strength.

Feed Rate

- Metering pump feed rate for a maximum day flow rate of 210 L/min requires a metering pump feed rate of 26 mL/min.
- Note: this is only valid for a solution concentration of 0.5 %.

Metering Pump Calibration

- Fill calibration cylinder on pump suction.
- Check draw down on calibration cylinder.
- Adjust stroke on metering pump for a given flow achieve desired draw down.